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Mathematical Modeling Of Seed Cotton and Lint Cleaning Systems

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Mathematical Modeling Of Seed Cotton and Lint Cleaning Systems

By K. H. Read and I. W. Kirk [1]

INTRODUCTION

Lint cotton is sold on the basis of a classer's grade index (based on trash content and color), a classer's staple, and micronaire. The monetary return to the cotton producer is directly related to these three factors plus lint turnout from ginning operations.

One approach to ginning for the return of the most money to the producer involves measuring characteristics of the incoming seed cotton, predicting the optimum seed cotton and lint cleaning system, and adjusting the system to process that cotton. For this approach to be feasible, mathematical models of seed cotton and lint cleaning systems are needed. The purpose of this study was to develop these models.

METHODOLOGY

The data needed to develop a system of mathematical models for use in determining the optimum cleaning system for maximizing producers' returns are outlined in table 1. The seed cotton cleaning system and the lint cleaning system were considered separately. Six dependent variables are set forth as output of the seed cotton cleaning system models. These variables are needed for use in predicting the values of five variables after the lint cleaning system. A sequence outlining how the producer's return could be calculated if these models were available is shown in table 2.

The data used in developing the required equations were collected by several ginning researchers over several years (table 3). These studies were not conducted to collect modeling data. Only data collected from studies where specific criteria were met were used. These criteria were as follows: (1) All seed cotton drying was done before the first seed cotton cleaning, (2) modern high-capacity saw gin stands were used, and (3) all machinery was adjusted conventionally and operated at normal speeds.

Equations were developed for specific machinery systems for which sufficient data were available instead of using individual cleaning machines as variables. All seed cotton cleaning systems included a feeder. Sequence of cleaning machines was neither a constant nor a model variable in the analyses.

Prediction equations were developed by stepwise multiple linear regression with the criterion that each independent variable included must be significant at the 5-percent level or higher. Probability plots of residuals were used as criteria to determine outlier data.

[1] Southwestern Cotton Ginning Research Laboratory, Mesilla Park, N. Mex.

TEST RESULTS

Seed Cotton Cleaning Systems

Turnout

Equations with four or five terms gave R^2 values from 0.64 to 0.93 (table 4).[2] Turnout appears to be reduced as feed rate is increased. Lower turnouts appear to be associated with longer cottons. Increased amounts of hulls, sticks, and motes appear to be associated with lower turnouts with the opposite effect for fine trash and total trash. Fine trash is more difficult to remove than larger trash. If a lint-to-seed ratio variable were included, the results might possibly be improved. Equations for different cleaning machinery systems include different variables.

An example will illustrate the use of the tables. The equation derived to predict seed cotton cleaning system turnout for one stick machine, one cylinder cleaner, and one feeder has the format

$$Y = A + b_1X_1 + b_2X_2 + b_3X_3$$

where Y is turnout, X_1 is percent fine trash at wagon, X_2 is percent lint moisture, and X_3 is feed rate. The values of the constants A, b_1, b_2, and b_3 are found from the table to be 44.1619, 1.5315, −0.2681, and −6.2676.

Leaf Index

Equations with two to four terms gave R^2 values from 0.45 to 0.75 (table 5). No patterns can be detected.

Lint Foreign Matter

Equations with four to six terms gave R^2 values from 0.80 to 0.99 (table 6). Lint foreign matter increased as wagon trash increased but decreased as a larger proportion of this trash was sticks. Higher lint moistures and higher feed rates were reflected in higher lint foreign matter. Higher micronaires were associated with lower lint foreign matter. Equations for different cleaning machinery systems include different variables.

[2] R^2 indicates the portion of the variability explained by the equation with 1.00 being equal to 100 percent.

Lint Reflectance

Equations with three to four terms gave R^2 values from 0.82 to 0.95 (table 7). Actual lint reflectance was positively correlated with the potential reflectance. Equations for the two cleaning machinery systems included different variables.

Lint Yellowness

Equations with four terms gave R^2 values from 0.85 to 0.91 (table 8). Longer span lengths were associated with decreased yellowness. Equations for the different cleaning machinery systems included different variables.

2.5-Percent Span Length

Equations with two terms gave R^2 values of 0.62 and 0.79 (table 9). The only trend is that the span length prior to lint cleaning varies with span length of the lint at the wagon. The regression coefficients were much different for the two cleaning machinery systems.

Lint Cleaning Systems

Turnout

Equations with three to five terms gave R^2 values from 0.52 to 0.91 (table 10). Turnout decreased as lint foreign matter before lint cleaning increased. Higher feed rates were associated with higher turnouts. Longer fibers were associated with higher turnouts. Micronaire and lint moisture effects were mixed. Equations for the different cleaning machinery systems included different variables except for the systems with the same sources of cotton.

Leaf Index

Equations with two to four terms gave R^2 values from 0.10 to 0.61 (table 11). Lower leaf indices were associated with lower lint foreign matter and shorter staple lengths. Equations for the different cleaning machinery systems included different variables even for the systems with the same sources of cotton.

Lint Reflectance

Equations with three to four terms gave R^2 values from 0.63 to 0.95 (table 12). Lint reflectance was adversely affected by higher feed rates and was positively affected by higher potential reflectances and higher reflectances before cleaning. Equations for the different cleaning machinery systems included different variables even when the same sources of cotton were used.

Lint Yellowness

Equations with two to four terms gave R^2 values from 0.87 to 0.90 (table 13). Higher lint yellowness was associated with higher foreign matter contents and longer fibers. Yellowness after lint cleaning was associated closely with yellowness before lint cleaning. Equations for the different cleaning machinery systems included different variables even when the same sources of cotton were used.

2.5-Percent Span Length

Equations with two to four terms gave R^2 values from 0.60 to 0.87 (table 14). Longer span lengths were associated with longer span lengths before lint cleaning and lower micronaires. Equations for the different cleaning machinery systems included different variables even when the same sources of cotton were used.

CONCLUSIONS

Prediction equations were developed for each cleaning machinery system for which sufficient data were available. The equations ranged from very poor to quite good as judged by the R^2 values. However, the mathematical models appear to be more useful as a guide for further work than for quantitative application.

The equations to predict a given dependent variable for the different cleaning machinery systems would be expected to include the same variables. Differences due to cleaning machinery systems should appear as differences in the coefficients and not result in different significant variables. The results do not follow the expected pattern and probably reflect the different data sets used. Therefore, the equations are not useful for the purposes intended.

The following are offered for consideration in further work on mathematical modeling of cotton ginning systems.

1. Variety differences may be important. They were not considered in this study.
2. Seasonal differences may be reflected in differences in cleaning characteristics. This possibility was not considered in this study.
3. Differences in procedures and techniques between laboratories sometimes result in different quantitative values for similar measurements on similar samples.
4. The different stick machines, cylinder cleaners, feeders, and lint cleaners were not all identical and probably did not produce identical results.
5. Some important variables may have been overlooked in this study.

Based on the results of this study, equations would probably have to be developed for a given gin plant for a given season. Variety differences might also have to be considered if several distinct types of cotton were ginned by one gin plant. In most cases, the seed cotton cleaning system could well remain unaltered with the producer's return being optimized by adjustments in the lint cleaning system. This approach has already been explored,[3] and research to implement such a system is underway.

[3] Read, K. H., and Leonard, C. G. A NEW SYSTEM TO DETERMINE LINT CLEANING. Cotton Ginners' Jour. and Yearbook 43(1): 54–57. 1975.

APPENDIX

TABLE 1.—*Independent variables and dependent variables used to model the seed cotton and lint cleaning systems*

Seed cotton cleaning system		Lint cleaning system	
Independent variables	Dependent variables	Independent variables	Dependent variables
Measurements on the material: Percent hulls at wagon. Percent sticks at wagon. Percent motes at wagon. Percent fine trash at wagon. Percent total trash at wagon. Fiber length at wagon. Lint moisture after drying. Micronaire after lint cleaning. Lint reflectance potential. Lint yellowness potential. System parameters: Seed cotton feed rate. Number of cylinder cleaners. Number of stick machines.	Seed cotton cleaning system turnout. Leaf index before lint cleaning. Lint foreign matter content before lint cleaning. Lint reflectance before lint cleaning. Lint yellowness before lint cleaning. Lint fiber length before lint cleaning.	Measurements on the material: Lint moisture after drying. Micronaire after lint cleaning. Lint reflectance potential. Lint yellowness potential. System parameters: Number of saw-type lint cleaners. Number of air-type lint cleaners. Output of seed cotton cleaning system models: Leaf index before lint cleaning. Lint foreign matter content before lint cleaning. Lint reflectance before lint cleaning. Lint yellowness before lint cleaning. Lint fiber length before lint cleaning. Calculated: Lint feed rate [1]	Lint cleaning system turnout. Leaf index after lint cleaning. Lint reflectance after lint cleaning. Lint yellowness after lint cleaning. Lint fiber length after lint cleaning.

[1] Calculated using the predicted seed cotton system turnout and the seed cotton feed rate.

TABLE 2.—*Determination of the producer's monetary return*

Lint reflectance (predicted) Lint yellowness (predicted)	Leaf index (predicted) Color index	Market prices Grade index Fiber[1] length (predicted) Micronaire (measured)	Lint value per pound	Producer's return per pound of seed cotton
		Lint system turnout (predicted) Seed cotton system turnout (predicted)	Combined system turnout	

[1] Price is actually based on the classer's staple length although the 2.5-percent span length is used in the models.

TABLE 3.—*Information concerning the source of data used to develop models*

Source number	Variety	Season	Ginning laboratory
1	Stoneville	1967	Stoneville
2	Coker	1969	Clemson
3	--do--	1970	Do.
4	--do--	1971	Do.
5	Acala 1517	1965	Mesilla Park
6	--do--	1966	Do.
7	--do--	1969	Do.
8	--do--	1970	Do.
9	--do--	1971	Do.
10	--do--	1973	Do.
11	Acala SJ-1	1970	Do.
12	--do--	1971	Do.
13	--do--	1972	Do.
14	Experimental	1973	Do.

TABLE 4.—*Equations for predicting seed cotton cleaning system turnout for 4 cleaning machinery systems (through a feeder and gin stand)*[1]

Data item	1 stick machine			2 stick machines
	1 cylinder cleaner	2 cylinder cleaners	3 cylinder cleaners	2 cylinder cleaners
b value for:				
Percent hulls at wagon	—	—	—	−0.6621
Percent sticks at wagon	—	—	−3.9444	—
Percent motes at wagon	—	−2.6768	—	—
Percent fine trash at wagon	1.5315	—	—	—
Percent trash at wagon	—	—	0.4284	—
Percent lint moisture	−.2681	—	—	—
Feed rate (lb/min/in)	−6.2676	−1.1669	−2.0638	−2.1722
Micronaire	—	—	—	2.7133
2.5-percent span length	—	−16.3285	−36.5465	—
Constant	44.1619	58.6520	81.1888	26.4987
Miscellaneous information:				
Number of terms	4	4	5	4
R^2 value	.64	.82	.93	.88
Standard error	1.42	0.77	0.66	0.66
Number of observations used	131	33	16	25
Data sources	2, 3, 4	12, 13, 14	12, 13	10, 13
Distribution of turnout:				
Mean	35.16	34.09	31.75	32.12
Standard deviation	2.32	1.73	2.21	1.78
Minimum	31.40	30.29	27.70	28.27
Maximum	41.20	35.86	35.40	34.39

[1] A dash indicates a variable was not significant at the 5-percent level.

TABLE 5.—*Equations for predicting classer's leaf index*[1] *prior to lint cleaning for 3 cleaning machinery systems*[2]

Data item	1 stick machine		2 stick machines
	2 cylinder cleaners	3 cylinder cleaners	2 cylinder cleaners
b value for:			
Percent hulls at wagon	—	—	—
Percent sticks at wagon	—	—	—
Percent motes at wagon	0.6396	—	—
Percent fine trash at wagon	—	—	—
Percent trash at wagon	—	—	—
Percent lint moisture	−0.1034	—	—
Feed rate (lb/min/in)	—	−1.2857	0.5791
Micronaire	—	—	−0.6364
2.5-percent span length	4.4836	—	—
Constant	−0.1623	8.5802	6.3375

See footnotes at end of table.

TABLE 5.—*Equations for predicting classer's leaf index*[1] *prior to lint cleaning for 3 cleaning machinery systems*[2]*—Continued*

Data item	1 stick machine		2 stick machines
	2 cylinder cleaners	3 cylinder cleaners	2 cylinder cleaners
Miscellaneous information:			
Number of terms	4	2	3
R^2 value	.75	.45	.52
Standard error	0.18	0.48	0.35
Number of observations used	32	16	26
Data sources	12, 13, 14	12, 13	10, 12, 13
Distribution of leaf index:			
Mean	5.12	4.88	4.95
Standard deviation	0.34	0.62	0.48
Minimum	5.0	4.0	4.2
Maximum	6.0	6.0	6.0

[1] Only first digit used for each classification.

[2] A dash indicates a variable was not significant at the 5-percent level.

TABLE 6.—*Equations for predicting lint foreign matter prior to lint cleaning for 4 cleaning machinery systems*[1]

Data item	1 stick machine			2 stick machines
	1 cylinder cleaner	2 cylinder cleaners	3 cylinder cleaners	2 cylinder cleaners
b value for:				
Percent hulls at wagon	—	—	—	—
Percent sticks at wagon	−3.1570	—	−3.4226	—
Percent motes at wagon	—	1.4789	—	—
Percent fine trash at wagon	—	—	—	—
Percent trash at wagon	0.8259	0.5766	1.0492	—
Percent lint moisture	0.5882	—	—	0.5650
Feed rate (lb/min/in)	1.0538	—	1.3917	1.9426
Micronaire	−0.8873	−0.6061	−4.0895	−4.0756
2.5-percent span length	—	8.3102	−24.8651	—
Constant	4.7112	−7.1353	43.9340	14.2858
Miscellaneous information:				
Number of terms	6	5	6	4
R^2 value	.80	.89	.99	.91
Standard error	0.97	0.43	0.45	0.51
Number of observations used	132	34	16	25
Data sources	2, 3, 4	12, 13, 14	12, 13	10, 13
Distribution of lint foreign matter:				
Mean	8.90	5.44	6.95	5.71
Standard deviation	2.16	1.22	3.73	1.59
Minimum	4.9	4.1	3.9	3.5
Maximum	19.4	8.2	16.0	8.9

[1] A dash indicates a variable was not significant at the 5-percent level.

TABLE 7.—*Equations for predicting lint reflectance prior to lint cleaning for 2 cleaning machinery systems* [1]

Data item	Number of stick machines (2 cylinder cleaners) 1	2
b value for:		
Percent hulls at wagon	—	—
Percent sticks at wagon	−1.8726	—
Percent motes at wagon	—	—
Percent fine trash at wagon	—	—
Percent trash at wagon	−0.3704	—
Percent lint moisture	—	—
Feed rate (lb/min/in)	—	4.6879
Micronaire	—	—
2.5-percent span length	—	—
Potential reflectance	0.4828	1.1939
Constant	41.7125	−22.7240
Miscellaneous information:		
Number of terms	4	3
R^2 value	.82	.95
Standard error	0.60	0.45
Number of observations used	24	16
Data source	14	10
Distribution of lint reflectance:		
Mean	76.56	76.64
Standard deviation	1.30	1.82
Minimum	74.2	74.1
Maximum	78.4	79.2

[1] A dash indicates a variable was not significant at the 5-percent level.

TABLE 8.—*Equations for predicting lint yellowness prior to lint cleaning for 2 cleaning machinery systems* [1]

Data item	Number of stick machines (2 cylinder cleaners) 1	2
b value for:		
Percent hulls at wagon	—	—
Percent sticks at wagon	—	—
Percent motes at wagon	0.7011	—
Percent fine trash at wagon	—	—
Percent trash at wagon	—	—
Percent lint moisture	—	—
Feed rate (lb/min/in)	—	1.3375
Micronaire	0.9506	—
2.5-percent span length	−3.0182	−5.0879
Potential yellowness	—	0.4619
Constant	7.1390	8.4872
Miscellaneous information:		
Number of terms	4	4
R^2 value	.85	.91

See footnote at end of table.

TABLE 8.—*Equations for predicting lint yellowness prior to lint cleaning for 2 cleaning machinery systems* [1]—*Continued*

Data item	Number of stick machines (2 cylinder cleaners) 1	2
Miscellaneous information:—Continued		
Standard error	0.22	0.12
Number of observations used	23	16
Data source	14	10
Distribution of lint yellowness:		
Mean	8.13	8.28
Standard deviation	0.53	0.37
Minimum	7.4	7.8
Maximum	9.0	9.0

[1] A dash indicates a variable was not significant at the 5-percent level.

TABLE 9.—*Equations for predicting lint 2.5-percent span length prior to lint cleaning for 2 cleaning machinery systems* [1]

Data item	Number of stick machines (2 cylinder cleaners) 1	2
b value for:		
Percent lint moisture	—	—
Feed rate (lb/min/in)	—	—
Micronaire	—	—
Wagon 2.5-percent span length	0.6210	0.2149
Constant	0.4531	0.9338
Miscellaneous information:		
Number of terms	2	2
R^2 value	.79	.62
Standard error	0.02	0.01
Number of observations used	22	7
Data source	14	10
Distribution of 2.5-percent span length:		
Mean	1.17	1.18
Standard deviation	0.04	0.01
Minimum	1.08	1.17
Maximum	1.23	1.20

[1] A dash indicates a variable was not significant at the 5-percent level.

TABLE 10.—*Equations for predicting lint cleaning system turnout for 6 cleaning machinery systems* [1]

Data item [2]	No air-type lint cleaner			One air-type lint cleaner		
	1 saw type	2 saw type	3 saw type	1 saw type	2 saw type	3 saw type
b value for:						
Percent total lint foreign matter (B.C.)	−0.7076	−0.6850	−0.4150	−0.7941	−0.4839	−0.4913
Percent lint moisture	0.2583	—	−0.3133	−0.4980	—	—
Lint feed rate (lb/min/in)	—	3.5284	4.5228	—	—	—
Micronaire (A.C.)	−0.7829	—	—	1.0184	−0.5298	−1.0475
2.5-percent span length (B.C.)	—	—	—	17.3938	11.4940	9.4778
Constant	102.2943	97.3349	95.6179	77.6247	84.4664	88.0066
Miscellaneous information:						
Number of terms	4	3	4	5	4	4
R^2 value	.83	.84	.88	.91	.61	.52
Standard error	0.85	0.79	0.67	0.55	0.49	0.48
Number of observations used	248	98	36	61	45	45
Data sources	1, 2, 3, 4, 5, 6, 7, 8, 13, 14	1, 2, 3, 4, 13, 14	2, 14	10, 11, 12, 13	11, 12, 13	11, 12, 13
Distribution of turnout:						
Mean	95.02	93.57	92.49	94.50	92.96	91.89
Standard deviation	2.05	1.92	1.82	1.80	0.73	0.67
Minimum	89.59	85.34	85.74	88.65	90.80	90.18
Maximum	98.13	97.04	94.94	96.87	94.41	93.31

[1] A dash indicates a variable was not significant at the 5-percent level.
[2] A.C., after lint cleaning; B.C., before lint cleaning.

TABLE 11.—*Equations for predicting classer's leaf index* [1] *after lint cleaning for 6 cleaning machinery systems* [2]

Data item [3]	No air-type lint cleaner			One air-type lint cleaner		
	1 saw type	2 saw type	3 saw type	1 saw type	2 saw type	3 saw type
b value for:						
Percent total lint foreign matter (B.C.)	0.0948	0.1309	—	0.1523	0.1904	—
Percent lint moisture	—	—	—	—	—	—
Lint feed rate (lb/min/in)	—	—	—	—	3.8901	—
Micronaire (A.C.)	—	—	—	—	—	—
2.5-percent span length (B.C.)	2.1309	6.1937	—	—	3.1512	1.6416
Leaf index code (B.C.)	0.4332	—	—	—	—	—
Constant	−1.2153	−4.6626	3.0000	3.1983	−2.1680	1.1062
Miscellaneous information:						
Number of terms	4	3	1	2	4	2
R^2 value	.44	.61	1.00	.38	.29	.10
Standard error	0.42	0.29	0.00	0.26	0.42	0.20
Number of observations used	129	36	24	61	45	45
Data source(s)	5, 6, 13, 14	13, 14	14	10, 11, 12, 13	11, 12 13	11, 12, 13

See footnotes at end of table.

TABLE 11.—*Equations for predicting classer's leaf index*[1] *after lint cleaning for 6 cleaning machinery systems*[2]*—Continued*

Data item[3]	No air-type lint cleaner 1 saw type	2 saw type	3 saw type	One air-type lint cleaner 1 saw type	2 saw type	3 saw type
Distribution of leaf index (A.C.):						
Mean	4.07	3.28	3.00	4.05	3.64	3.04
Standard deviation	0.55	0.45	0.00	0.32	0.48	0.21
Minimum	3.0	3.0	3.0	3.5	3.0	3.0
Maximum	5.0	4.0	3.0	5.0	4.0	4.0

[1] Only the first digit was used for each classification.
[2] A dash indicates a variable was not significant at the 5-percent level.
[3] A.C., after lint cleaning; B.C., before lint cleaning.

TABLE 12.—*Equations for predicting lint reflectance after lint cleaning for 4 cleaning machinery systems*[1]

Data item[2]	No air-type lint cleaner 1 saw type	2 saw type	3 saw type	One air-type lint cleaner 1 saw type
b value for:				
Percent total lint foreign matter (B.C.)	—	—	—	—
Percent lint moisture	—	—	—	−0.5354
Lint feed rate (lb/min/in)	−10.6393	−19.8070	−22.0754	—
Micronaire (A.C.)	—	—	—	—
2.5-percent span length (B.C.)	−12.6656	—	—	—
Lint reflectance (B.C.)	—	0.3844	0.3583	0.7371
Potential lint reflectance	1.4269	0.3574	—	—
Constant	−17.4194	27.3922	59.1727	24.7839
Miscellaneous information:				
Number of terms	4	4	3	3
R^2 value	.69	.72	.63	.95
Standard error	0.66	0.56	0.50	0.36
Number of observations used	24	24	24	16
Data source	14	14	14	10
Distribution of lint reflectance (A.C.):				
Mean	78.36	78.90	79.43	78.26
Standard deviation	1.11	0.97	0.80	1.43
Minimum	76.0	77.0	77.0	76.4
Maximum	79.8	80.8	80.8	80.3

[1] A dash indicates a variable was not significant at the 5-percent level.
[2] A.C., after lint cleaning; B.C., before lint cleaning.

TABLE 13.—*Equation for predicting lint yellowness after lint cleaning for 4 cleaning machinery systems* [1]

Data item [2]	No air-type lint cleaner			One air-type lint cleaner
	1 saw type	2 saw type	3 saw type	1 saw type
b value for:				
Percent total lint foreign matter (B.C.)	—	0.1713	—	0.1373
Percent lint moisture	—	−0.4029	—	—
Lint feed rate (lb/min/in)	—	—	—	—
Micronaire (A.C.)	—	—	—	—
2.5-percent span length (B.C.)	—	—	4.2563	—
Lint yellowness (B.C.)	0.9850	0.6233	1.1933	—
Potential lint yellowness	—	—	—	0.5198
Constant	0.4342	4.6425	−5.9812	3.0331
Miscellaneous information:				
Number of terms	2	4	3	3
R^2 value	.88	.87	.90	.89
Standard error	0.20	0.21	0.19	0.16
Number of observations used	24	24	24	16
Data source	14	14	14	10
Distribution of lint yellowness (A.C.):				
Mean	8.41	8.51	8.58	8.56
Standard deviation	0.56	0.54	0.59	0.44
Minimum	7.6	7.6	7.8	8.0
Maximum	9.2	9.3	9.4	9.2

[1] A dash indicates a variable was not significant at the 5-percent level.
[2] A.C., after lint cleaning; B.C., before lint cleaning.

TABLE 14.—*Equations for predicting lint 2.5-percent span length after lint cleaning for 6 cleaning machinery systems* [1]

Data item [2]	No air-type lint cleaner			One air-type lint cleaner		
	1 saw type	2 saw type	3 saw type	1 saw type	2 saw type	3 saw type
b value for:						
Percent lint moisture	—	0.0023	0.0044	—	−0.227	—
Lint feed rate (lb/min/in)	—	—	—	—	0.1632	—
Micronaire (A.C.)	—	—	−0.0329	—	—	−0.0206
2.5-percent span length (B.C.)	0.9494	0.7179	0.5214	0.8096	0.3520	0.6579
Constant	0.0509	0.2877	0.6345	0.2122	0.8518	0.4719
Miscellaneous information:						
Number of terms	2	3	4	2	4	3
R^2 value	.84	.60	.75	.87	.70	.83
Standard error	0.02	0.02	0.01	0.02	0.02	0.01
Number of observations used	183	102	36	61	45	45
Data sources	1, 2, 3, 4, 5, 6, 14	1, 2, 3, 4, 13, 14	2, 14	10, 11, 12, 13	11, 12, 13	11, 12, 13
Distribution of 2.5-percent span length (A.C.):						
Mean	1.17	1.12	1.12	1.16	1.16	1.16
Standard deviation	0.04	0.02	0.03	0.04	0.03	0.04
Minimum	1.09	1.08	1.06	1.06	1.12	1.11
Maximum	1.27	1.17	1.17	1.24	1.23	1.22

[1] A dash indicates a variable was not significant at the 5-percent level.
[2] A.C., after lint cleaning; B.C., before lint clea

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